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10 ECOLOGICAL HEALTH RISK EVALUATION

10.1 INTRODUCTION

10.1.1 Overview

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) was tasked to conduct a field investigation of the Firing Range at Jefferson Proving Ground (JPG) in order to evaluate the potential chemical impact of past live-fire range testing operations on ground water, surface water, soil, plants, and animals. A human health and ecological risk assessment (ERA) was conducted to evaluate data collected during the field investigation. This report focuses on the ecological risk assessment.

10.1.2 Objective

Since JPG has been inactive since 1995, the objective of this field investigation was to determine if live-fire artillery testing activities have caused adverse ecological impacts, specifically due to chemical contamination explosives residues.

10.2 RATIONALE AND METHODS

10.2.1 Rationale

A weight of evidence approach was used to determine if artillery testing activities have caused adverse ecological impacts. Rodents were selected as the receptors of concern since they have a high degree of contact with potentially contaminated site media, consume a large amount of vegetative matter, and are prey for many predatory species. Differences in sperm parameters were selected as the endpoints in this evaluation since they indicate potential reproductive effects which could impact the rodent population. Since the cause of differences in sperm parameters cannot be definitively determined, other measures were used to establish causality, and to determine if rodents are exposed to substances of potential concern (SOPCs). These included vegetation and soil sampling to determine potential exposures via ingestion, and organ to body weight ratio analysis and histopathological evaluation to generate evidence that rodents have been exposed to SOPCs. Finally, hazard quotients were calculated to determine if rodents are estimated to have adverse effects due to SOPC exposure. The information generated from each of these methods was evaluated in total to determine if the rodent population is at risk due to reduced reproductive success as determined by Rodent Sperm Analysis (sperm parameters), and to determine if the differences seen in sperm parameters are attributable to SOPC exposure.

10.2.2 Problem Formulation

Problem formulation begins during the planning processes for an investigation and is designed to focus the investigation to receptors of concern and potentially contaminated media. The result of the problem formulation stage was the development of a conceptual site model that details media that may be contaminated, transport route of potential contamination, and ecological receptors that are potentially exposed to contaminated media.

The conceptual site model considers both the potential physical and chemical stressors associated with firing range activities. The focus of this investigation was to identify potential ecological threats posed by chemical stressors caused by past firing range operations. However, physical stressors may have more of an effect on the ecosystem than chemical stressors. It is difficult to filter out the effects of physical vs. chemical stressors on the ecosystem. JPG offers a unique opportunity to more closely evaluate the chemical effects of artillery firing since this range was last used in 1995. Therefore, if impacts are seen, they cannot be caused by the physical disturbance characteristic of artrillery firing.

10.2.3 Assessment Endpoints

The structure of the wet meadow ecosystem was selected as the assessment endpoint. The wet meadow ecosystem was selected since this ecosystem is the dominant ecosystem on impact areas at JPG. Effects to the wet meadow ecosystem are discussed.

10.2.4 Measurement Endpoints

Due to the limited access to the range, a thorough assessment of the entire range ecosystem was not possible. Organisms were chosen based on their importance to the structure of the ecosystem and their potential for exposure to artillery-generated SOPCs. Evaluating only two components of a system cannot fully characterize a change in ecosystem structure. Nevertheless, rodents and plants were chosen for evaluation because they are important components of the ecosystem structure. It is assumed that if the rodent population is exhibiting deleterious effects attributable to SOPC exposure, then the structure of the system may also be impacted. The specific measurement endpoints for vegetation included analysis of two plant species for contaminant uptake and a qualitative assessment of the vegetative community. Rodents were evaluated for sperm effects (sperm count, motility and morphology), organ to body weight ratios, and histopathology.

10.3 FLORA AND FAUNA FOUND AT JPG

10.3.1 Vegetation

Upland forests comprise 27,000 acres (54%) of the 50,000-acre refuge. The upland forest classification includes both evergreen and deciduous species ranging in age from young(~15-30 years) to mature (>50 years). The primary evergreen species at the site is eastern red cedar (*Juniperus virginiana*). Dominant deciduous trees include sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*) on poorly drained upland depression sites. Tulip poplar (*Liriodendron tulipifera*) and white ash (*Fraxinus americana*) are the species making up the young upland forests on well drained sites. White oak (*Quercus alba*), red oak (*Quercus rubra*) and shagbark hickory (*Carya ovata*) are the dominant species on intermediate and within some mature upland forests. American beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*) dominate the remainder of the mature upland forests.

The second most abundant habitat at JPG is grasslands. This habitat type makes up 8,500 acres (17%) of the area. The dominant grassland species at the site appears to be broomsedge (*Andropogon sp.*). Other habitat types at JPG include 5,000 acres (10%) palustrian wetland,

3,000 acres (6%) woodland, 6,000 acres (12%) early successional shrubland, 250 acres (0.5%) of open water, and 250 acres (0.5%) of bare soil and paved areas. The palustrine wetland category includes all growth stages of palustrine vegetation including early successional and forested wetland. A total of 46 state-listed plant species are found on JPG (see Appendix A of QAPP ERA SAP).

10.3.2 Wildlife

The JPG provides habitats for, and subsequently attracts, an abundance of wildlife species. Eight freshwater mussels species, 41 fish species, 24 amphibian species,
17 reptile species, 46 mammal species, and 201 bird species have either been recorded or can reasonably be expected to be present for a portion of the year. The state-endangered river otter was reestablished on JPG in 1996 (USFWS, 2000).

The wide array of both resident and migratory species found at JPG is due to the grassland/forest/wetland complex found within the landscape of the installation. These large habitat blocks of forests, shrublands, grasslands, forested wetlands, and occasional emergent marsh contribute to the increased biodiversity of the natural communities found at the refuge.

Biodiversity is enhanced at the site by the presence of area-sensitive species; for example, species such as Henslows sparrow and cerulean warblers, which require large blocks of grassland and mature forest respectively, are relatively common on JPG.

Habitat management activities at the refuge emphasize numerous goals which include; enhancement of existing wetlands, active management of grassland and shrubland areas, and the protection of late second-growth forests and wooded wetlands. All of these habitat management activities are designed to benefit populations of native fish and wildlife species.

The value of the habitat within the proposed refuge has been recognized at both the state and national levels. The Big Oaks National Wildlife Refuge (NWR) was named a Globally Important Bird Area by the American Bird Conservancy due to large Henslows sparrow populations within the grassland areas. The Indiana Department of Natural Resources states that, "JPG is indeed a natural treasure that contains a full array of the regions natural communities and species assemblages." (USFWS, 2000).

10.4 STUDY SITES

Three study sites were selected representing a high explosive (HE) impact area, a depleted uranium (DU) impact area, and a comparison area (CA), (a site not used for artillery firing activities) to collect rodent and vegetation samples. The three locations were chosen based on similarity of vegetative communities, habitat for rodent species, topography, soil types, geology, hydrology, and historical use.

10.4.1 Study Site Descriptions

4.5W is an impact area that received HE round impacts based on historical documentation and personal communications with installation personnel. 4.5W is a heavily cratered shrub scrub successional wet meadow dominated by willow, sweet gum, oak, and forbs. This site will be designated as HE for the purposes of the ERA.

7.5 CF is located on the north central portion of the DU area and received both HE and DU round impacts (Figure 10-1). 7.5 CF is a shrubby successional wet meadow dominated by willow, sweet gum, oak, and forbs. This area will be designated as DU for the purposes of the ERA.

10.4.2 Comparison Area

The initial CA was selected during a site scoping visit in April and was located near gate 15 on the western boundary of the installation. The site appeared to contain similar vegetation, hydrology, and habitat as the impact area sites during the May, 2002 scoping visit. However, upon returning to the installation in September to conduct trapping, it was apparent that the comparison site vegetation and hydrology were different from the impact area sites. Traps were set on this site for 2 nights with no success most likely due to habitat and heavy rains. It was decided to conclude trapping on this site, select a different comparison site, and to return in 2 weeks to trap the new comparison location. The new comparison site (DA) was located near gate 5 on the eastern boundary of the installation. The site was used as an unexploded ordnance (UXO) detection technology demonstration site by the Army Environmental Center (AEC). In this demonstration, inert rounds were placed on the site and their locations were noted. Various UXO detection technologies were employed to determine the locations of the duds and remove them. After discussions with installation and AEC personnel, it was decided that the possibility that these inert rounds could have caused environmental contamination was low. This was due to their short duration in the field, 100% recovery of the rounds placed on the site, and the fact that they were inert (i.e., did not contain HE). No other sites on the installation were suitable for use as a comparison area. The vegetation of the comparison area is characterized by wet meadow vegetation. Two of the four grids are dominated by successional wet meadow, with the remaining two characterized by wet and upland meadow vegetation.

Soils were analyzed at the DA site, and qualitatively compared to soils collected from within trap grids on the HE and DU areas (Table 10-1). A qualitative comparison was conducted since the sample population was small (2 samples from DU and HE and 4 samples from DA). The only explosive detected in either DU or HE samples was RDX at 0.014 ppm. The explosives detected in DA soils included 2,4,6 TNT (max = 0.43 ppm, average = 0.16 ppm), RDX (max = 1.7 ppm, average = 0.99 ppm), and HMX (max = 0.82 ppm, average = 0.21 ppm). Thus, the DA soils are more contaminated by explosives than DU or HE soils. Metals concentrations were also generally greater in DA soils than in HE or DU soils.

FIGURE 10-1 RODENT TRAPPING AND VEGETATION SAMPLING GRIDS

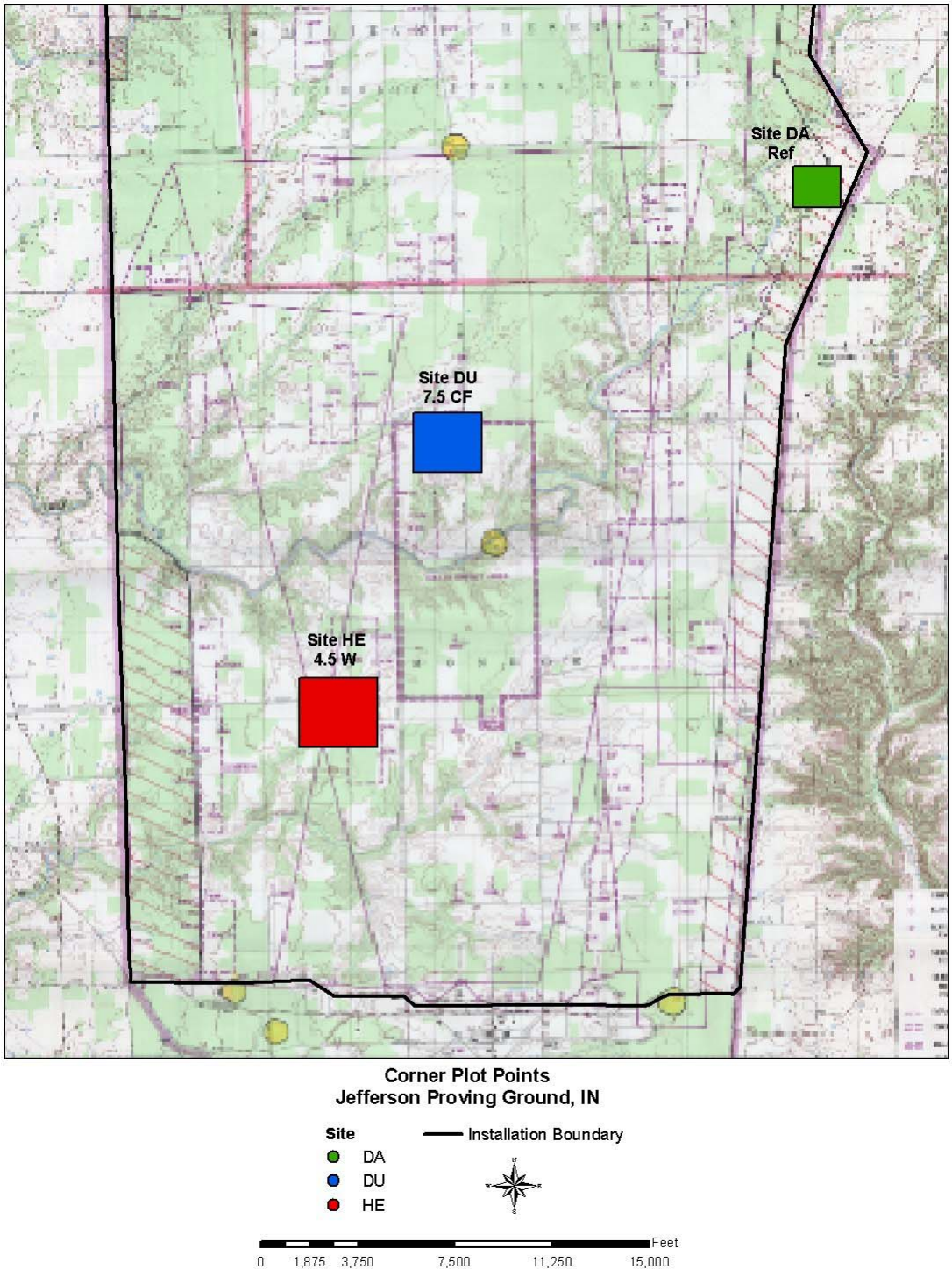

TABLE 10-1 SOIL SAMPLE RESULTS FROM 4 SOIL SAMPLES TAKEN FROM DA AREA. HE AND DU RESULTS ARE SHOWN SO QUALITATIVE COMPARISON CAN BE PERFORMED

Analyte	Sample area			
	HE	DU	DA	
	average (ppm)	average (ppm)	maximum (ppm)	average (ppm)
EXPLOSIVES				
2,4,6-Trinitrotoluene (TNT)	nd	nd	0.43	0.16
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.014	0.025	1.7	0.99
HMX	nd	nd	0.82	0.21
METALS				
arsenic	6.3	3.3	16.4	8.47
barium	78.5	43.4	134	80.5
chromium	8.62	8.24	52.8	25.7
copper	47.4	5.55	nd	nd
lead	17.1	11.1	37.5	22.9
manganese	690	35.3	2500	2161
mercury	nd	nd	0.0711	0.0358
nickel	6.48	2.74	nd	nd
vanadium	27.5	19.7	53.4	37.7

10.5 METHODS

10.5.1 Rodent Trapping

Meadow voles (*Microtus pennsylvanicus*) were used to assess the potential impact of artillery firing activities by comparing sperm parameters (i.e., sperm count, motility, and morphology) in rodents captured from the three study sites.

Each sampling site was divided into quadrants and numbers (1-4) uniquely identified the quadrants. The quadrants served as the template for biota sampling (i.e., placement of trap grids and vegetation sampling).

Traps were set in a grid format consisting of 100 traps. The grid consisted of 10 rows spaced approximately 10 m apart. Each row contained 10 traps with approximately 10 m between traps along the row. To maximize trap success, traps were strategically placed in preferable habitat and in areas where there was evidence of rodents (i.e., runs). The traps were left open for 3 consecutive nights on two diagonal quadrants (i.e., 1 and 4). On the fourth morning, the grids were relocated to the two remaining diagonal quadrants within the sampling site (i.e., 2 and 3). The traps remained open for 3 more nights. On the sixth morning trapping was concluded and all traps were removed from the trapping location. The grids on HE and DU areas were trapped concurrently for 6 nights. The traps were moved to the DA 2 weeks later for 6 nights of trapping.

The traps were discretely numbered (1-100) for each grid and placed in the grid formation, and were baited with a sweet feed horse mixture. Cotton balls were placed in each trap to provide nesting material for captured rodents. Traps were set during the late afternoon and were checked within the first 2 hours of sunrise each morning.

Captured animals were temporarily placed in zip-loc bags for field evaluation to determine species, sex, and age. All animals were weighed using a Pesola scale, which was calibrated daily and zeroed to account for bag weight. A Global Positioning System (GPS) with an accuracy of 3 meters was used to map each trap location where rodents were captured. Dominant vegetation surrounding each capturing trap was documented.

Females and juvenile males were marked by clipping fur from the rump and released. Adult males were transported to the field laboratory in the trap they were captured in. Sperm analysis was performed by a technician from Pathology Associates (PAI). The methods used by PAI are included in Appendix F. Wet weights were obtained for livers, spleens, and epididymis. These organs were also inspected for gross abnormalities, and tissues were harvested for histopathological analysis. Percent differences were calculated by dividing the mean of each parameter evaluated on the impact area by the mean of that parameter on the comparison area, subtracting the quotient from 1 and multiplying by 100.

10.5.2 Vegetation

The vegetative community dominating the impact area is successional wet meadow and is composed primarily of shrubs, young trees, grasses, and forbs. Woolgrass and broomsedge were found on each of the study and comparison sites. The plants and seeds are consumed by avian and mamallian species. Therefore, these two plants were selected to be sampled for heavy metals and explosives (Table 10-2) and perchlorate uptake. Only aboveground portions of plants were sampled.

Vegetation samples were picked by hand and placed in clean plastic bags. A minimum wet weight of 100 g was obtained for each sample. All vegetation samples were placed on ice immediately upon collection and were maintained at 4^{o}C. Woolgrass samples were composed of approximately of 50% seed head and 50% basal leaf. Vegetation samples were not washed in the field, or in the laboratory to provide a worst-case estimate of potential contaminant exposure to rodents. Thus, any contaminants found in vegetation samples may not reflect true contaminant uptake since it is unclear what contaminant concentration is actually in the plant vs. what is on the surface of the plant.

Eighteen broom sedge and 18 woolgrass samples were collected from each study area.
A duplicate sample was taken from the fifth sample on each area.

TABLE 10-2 HEAVY METAL AND EXPLOSIVE ANALYTES

HEAVY METALS
antimony
arsenic
barium
cadium
chromium
copper
lead
manganese
mercury
molybdenum
nickel
silver
uranium
vanadium

Explosives
1,3,5-Trinitrobenzene
1,3-Dinitrobenzene
2,4,6-Trinitrotoluene (TNT)
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Amino-4,6-dinitrotoluene
2-Nitrotoluene
3-Nitrotoluene
4-Amino-2,6-dinitrotoluene
4-Nitrotoluene
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)
HMX
Nitrobenzene

10.6 DATA EVALUATION

All data were evaluated using SPSS software. Data were checked for normality using the Shapiro-Wilk test. Data found to be non-normally distributed were log transformed and were reevaluated for normality. The means of the data sets were compared using a one tailed t-test. If data were not normally or log normally distributed they were compared using the Mann Whitney u test.

Parameters were compared statistically between the comparison, HE, and DU rodent populations to determine if differences seen can be attributed to chance or if the differences are real. However, statistical significance does not necessarily indicate biological significance, and the lack of statistical significance does not indicate the lack of biological significance. P values from the t test results are reported. P values > .05 were considered significant.

10.7 RODENT RESULTS

Meadow voles (*Microtus pennsylvanicus*) were captured on all three study sites and adult males were used for Rodent Sperm Analysis. Other species caught on JPG included *Microtus ochrogaster* (Prairie Vole), *Cryptotis parva* (Least shrew), *Peromyscus leucopus* (White-footed mouse), and *P. maniculatus* (Deer Mouse). Table 10-3 summarizes the number of animals captured on each site.

TABLE 10-3 NUMBER OF ANIMALS CAUGHT BY SAMPLING LOCATION

Species	Impact Areas		Comparison Area
	HE	DU	DA
Microtus pennsylvanicus (Meadow Vole	21	10	41
Microtus ochrogaster (Prairie Vole)	1	3	0
Cryptotis parva (Least Shrew)	0	1	0
Peromyscus leucopus (White-footed Mouse)	1	0	0
Peromyscus maniculatus (Deer Mouse)	1	0	1

The results of the rodent data collected (sperm analysis and organ:body weight ratios) from adult male *M. pennsylvanicus* are found in Table 10-4.

TABLE 10-4 RODENT DATA RESULTS

Parameter	M. PENNSYLVANICUS		
	HE	DU	DA
Sperm Count (10^6 sperm/g epididymis)	1922.1[a]	1866.9[b]	2498.6[b]
Sperm Morphology (% abnormal sperm)	0.3	1.4	0.9
Sperm Motility (% motile)	84	73	76
Liver: Body Weight Ratio	3.9282[a]	3.9382[b]	4.6008[b]
Epididymis: Body Weight Ratio	0.1466[a]	0.1601[a]	0.1460[a]
Spleen: Body Weight Ratio	0.1898[a]	0.1080[b]	0.2447[a]
Kidney: Body Weight Ratio	1.2327[a]	1.1093[b]	1.0687[b]
Male Body Weight (grams)	38.2070[a]	35.1973[b]	40.1532[a]

[a,b] Means with uncommon subscripts between the appropriate comparisons (HE vs DA and DU vs DA) differ ($P < 0.05$).

10.7.1 Sperm Count

M. pennsylvanicus sperm count was significantly reduced by 23.07% on the HE area ($p = .045$) as compared to the DA area. Sperm count was reduced by 25.28% on the DU area but the difference between DU and DA was not significant ($p = .068$).

10.7.2 Sperm Morphology

Individuals taken from the HE area had 0.3% abnormal sperm. *M. pennsylvanicus* had 1.4 and 0.9% abnormal sperm on the DU and DA, respectively. These are straight percent abnormal sperm calculated by evaluating the number of abnormal sperm per 200 sperm sampled. There were no statistical differences observed in sperm morphology between the reference and impact sites.

10.7.3 Sperm Motility

The percent motile sperm for *M. pennsylvanicus* from the HE area was 84%. The DU area voles were reported to have 73% motile sperm. These percent motile sperm values for the impact

areas were compared to the DA area value of 76%. Therefore, HE had 8% more motile sperm and the DU rodents had 3 % less motile sperm as compared to DA. The observed differences in sperm motility between the impact and reference areas were not statistically significant.

10.7.4 Liver:Body Weight Ratios

Male *M. pennsylvanicus* liver:body weight ratios were reported as significantly reduced by 14.63% on the HE area ($p = 0.028$). Liver:body weight ratios were reduced by 14.41% on the DU area; however, this difference was not significant ($p = 0.069$).

10.7.5 Epididymis:Body Weight Ratios

M. pennsylvanicus epididymis:body weight ratios were not different between HE and the comparison areas ($p = 0.47$). Epididymis:body weight ratios were 9.37% larger on the DU area; however, this difference was not significant ($p = 0.28$).

10.7.6 Spleen:Body Weight Ratios

M. pennsylvanicus spleen:body weight ratios were reduced by 18.93% on the HE area as compared to DA; however, this difference was not significant ($p = 0.38$). Spleen:body weight ratios were significantly reduced by 54.16% on the DU area ($p = 0.045$).

10.7.7 Kidney:Body Weight Ratios

M. pennsylvanicus kidney:body weight ratios were significantly increased by 13.38% on the HE area ($p = 0.053$) as compared to DA rodents. Kidney: body weight ratios on the DU area were increased by 3.70%; however, this difference was not significant ($p = 0.295$).

10.7.8 Male Body Weight

Male *M. pennsylvanicus* body weights were not significantly reduced on HE by 4.84% ($p = 0.175$) as compared to DA. They were significantly reduced on DU by 12.34% ($p = 0.039$).

10.7.9 Histopathology

The histopathological evaluation found no significant differences in the liver, spleen, kidneys, and testes between the HE, DU, and DA area animals. Incidental background and/or parasitic findings were noted in all tissues and in all areas.

10.8 VEGETATION RESULTS

Vegetation was analyzed for heavy metals and explosives. Table 10-5 shows the detection levels for heavy metals. If the metal is not listed, there was not a detection. For explosives, nitrobenzene was detected in two broomsedge and two woolgrass samples collected from the HE

area, and one woolgrass sample collected from the DU area. The concentration in every sample was 0.2 ppm, which is below the method reporting limit. In addition, the same concentration was detected in a laboratory blank. Therefore, it was determined these concentrations were false positives, and it was concluded that no explosive compounds were found in vegetation.

10.8.1 Woolgrass

Barium concentrations in woolgrass were not different between the sites (p = 0.666 for DA vs. HE, p = 0.387 for DA vs. DU). Average concentration on the HE area was 25.18 ppm, 17.64 ppm on DU, and 23.92 ppm on DA.

Copper concentrations in woolgrass were not different between the sites (p = 0.114 for DA vs. HE, p = 0.23 for DA vs. DU). Average concentration on the HE area was 8.34 ppm, 8.82 ppm on DU, and 9.36 ppm on DA.

Manganese concentrations in woolgrass were not different between the sites (p = 0.094 for DA vs. HE, p = 0.094 for DA vs. DU). Average concentration on the HE area was 809.22 ppm, 803.67 ppm on DU, and 1046.11 ppm on DA.

Nickel concentrations in woolgrass were not different between the sites (p = 0.387 for DA vs. HE, p = 0.190 for DA vs. DU). Average concentration on the HE area was 2.112 ppm, 1.832 ppm on DU, and 2.57 ppm on DA.

10.8.2 Broomsedge

Barium concentrations in broomsedge were not different between the sites (p = 0.317 for DA vs. HE, p = 0.084 for DA vs. DU). Average concentration on the HE area was 11.20 ppm, 13.898 ppm on DU, and 9.63 ppm on DA. Copper concentrations in broomsedge were significantly elevated on the DA area compared to the HE area (p = 0.017 for DA vs. HE). Concentrations were not different between the DA and DU areas (p= 0.138 for DA vs. DU). Average concentration on the HE area was 3.02 ppm, 3.41 ppm on DU, and 3.80 ppm on DA.

Manganese concentrations in broomsedge were significantly elevated on the DA area compared to the HE area (p = 0.001 for DA vs. HE). Concentrations were also significantly elevated on the DA area compared to the DU area (p= 0.006 for DA vs. DU). Average concentration on the HE area was 182.67 ppm, 255.67 ppm on DU, and 297.78 ppm on DA.

TABLE 10-5 ANALYTICAL RESULTS FOR HEAVY METALS FROM VEGETATION SAMPLES COLLECTED ON IMPACT AREAS (HE = HIGH EXPLOSIVE; DU = DEPLETED URANIUM) AND THE COMPARISON AREA (DA). ANALYTE CONCENTRATIONS ARE IN PPM AND REPRESENT AVERAGE CONCENTRATIONS

Analyte (ppm)	Woolgrass			Broomsedge		
	HE	DU	DA	HE	DU	DA
Barium	25.18[a]	17.64[a]	23.92[a]	11.20[a]	13.898[a]	9.63[a]
Copper	8.34[a]	8.82[a]	9.36[a]	3.02[a]	3.41[c]	3.80[b,c]
Manganese	809.22[a]	803.67[a]	1046.11[a]	182.67[a]	255.67[a]	297.78[b]
Nickel	2.112[a]	1.832[a]	2.57[a]	nd[d]	nd	nd

[d] nd = non-detect

10.9 RODENT DISCUSSION

There are two primary concerns associated with potential chemical risks at Army firing ranges: 1) impacts to prey species and 2) impacts to predator species through either contaminant toxicity or reduced prey availability. Since explosives and the metals found on Army firing ranges are not expected to bioaccumulate (Whaley and Leach, 1994, USACHPPM, 2002; Torres and Johnson, 2001), prey species are not evaluated for body burden. Therefore, predatory species are not expected to be exposed to SOPCs via prey. However, some of the explosives and metals expected to occur on Army ranges are known to cause reproductive effects in mammals (Das and Dasgupta, 2000; Kempinas et al., 1988; Laskey et al., 1984). Thus, there is potential for reproductive effects in the small mammal population. If small mammal populations are impacted, predator populations may also be impacted due to reduced prey availability.

10.9.1 Sperm Count

The cause of the observed sperm count reductions in *M. pennsylvanicus* cannot be definitively established. It is possible that chemical contamination, specifically exposure to explosives, is the causative agent of the reductions. However, accepted measures of contaminant exposure (i.e., increased liver weight and reduced epididymis weight; Chapin et al., 1997; Dilley et al., 1982; Levine et al., 1984; histopathological changes) were not observed. In addition, the fact that the reference area was more contaminated than the impact area indicates that the observed sperm count reductions were not caused by exposure to contaminants. However, it may be possible to see a change in sperm parameters with no observed change in organ to body weight ratio. There are other factors that can potentially cause sperm count reduction. Certain mammalian species are known to change reproductive effort such as delay to sexual maturity as available resources change (Glass et al., 1984; Glass et al., 1987).

Thus, it is possible that reduced sperm count is an effect of, or response to reduced resource availability. It is known that rodent populations naturally cycle. It is not established whether these fluctuations are predator or density-dependent. There is increasing evidence indicating that rodent population fluctuations may be density driven (Agrell, et al., 1995). It is possible that the observed decrease in sperm count in *M. pennsylvanicus* is a density mediated response to reduce the population. However, we have not investigated this theory.

Several authors have reported that sperm output for rats or mice must decrease by 80-99% before a reduction in fertility is seen (Aafjes et al., 1980; Meistrich et al., 1982; Robaire et al., 1984 Grey et al., 1992). Therefore, it is concluded that rodents are robustly fertile (Meistrich, et al., 1994; Gray, et al., 1992). Dewsbury and Sawrey (1984) found that a 75% reduction in sperm count had no effect on reproductive success in *Peromyscus maniculatus*. There is some evidence indicating that a small reduction in sperm count may result in a reduction in reproductive success and thus population. Chapin et al. (1997), found an association between sperm count and fertility and reported that small reductions in sperm count (approximately greater than 20%) result in reduced fertility. However, the bulk of the scientific evidence available indicates that an 80% reduction in sperm count is necessary before a reduction in fertility is seen. Therefore we assumed that an 80% reduction in sperm count from the comparison site condition is needed to conclude that reproductive success is compromised. *M. pennsylvanicus* sperm count was reduced by 23.07% on the HE area and 25.28% on the DU area as compared to the comparison site. These reductions are well below the established 80% threshold, indicating that these reductions will have no effect on rodent population. In addition, the sperm count reductions cannot be linked to chemical exposure as discussed above.

10.9.2 Sperm Morphology

Abnormal sperm morphology can be caused by chemical stressors (Chapin et al., 1997) and may also occur normally in a population. The incidence of abnormal sperm has not been investigated in wild rodent populations. *M. pennsylvanicus* had a lesser incidence of abnormal sperm on the DU area than the DA area. However, *M. pennsylvanicus* had a greater incidence of abnormal sperm on the HE area as compared to DA. The lack of consistency in results (increased abnormal sperm on comparison site as compared to HE site) indicate that the observed abnormalities are due to factors other than chemical stressors.

In addition, the observed differences (1.4% abnormal on DU, .3% abnormal on HE and .85% abnormal on DA) were well below the 4% difference needed to cause a reproductive effect as established by Chapin, et al., 1997.

10.9.3 Sperm Motility

The observed differences in sperm motility between the impact and reference areas were not statistically significant. In addition, these differences (3.9 % less motile on DU and 9% more motile on HE as compared to reference) are both well below the 40% threshold needed before a reproductive effect is realized.

10.9.4 Organ:Body Weight Ratios

Changes in organ:body weight ratios can indicate exposure to chemical stressors (Chapin et al., 1997; Dilley et al., 1982; Levine et al., 1984). Increased liver weights typically indicate exposure to a chemical stressor since the organ must compensate to remove the toxic, resulting in an increased mass.

M. pennsylvanicus livers were not significantly smaller on the HE and DU areas as compared to the DA area. *M. pennsylvanicus* spleen masses were not significantly reduced on the DU area, but were not different between the DA and HE sites. Kidney to body weight ratios were not significantly greater on the HE site compared to DA and were not different on the DU area as compared to DA. Chapin et al. (1997), found reduced epididymis weights in rats exposed to chemical stressors. The epididymis to body weight ratios for *M. pennsylvanicus* were not different between the HE and DA sites. Epididymis to body weight ratios were not significantly greater on the DU area.

While a clear determination of exposure cannot be made based on differences in organ:body weight ratios, it appears that *M. pennsylvanicus* are not exposed to SOPCs at JPG, since no trends in organ:body weight ratios indicate exposures are apparent.

10.9.5 Histopathology

The histopathological investigation did not find any differences in spleen, liver, kidney or testes in animals harvested from the impact and reference areas that can be linked to potential SOPC exposure at the HE or DU areas. Therefore, it appears that rodents at JPG are not exposed to SOPCs at this site.

10.10 VEGETATION DISCUSSION

The vegetation data was used to calculate hazard quotients (HQs) for rodents, and does not indicate the health of the vegetative community. The plant species sampled were expected to provide a worst-case dietary exposure to rodents since vegetation was sampled near impact craters on the impact areas.

Barium, copper, manganese, and nickel were detected in woolgrass samples. Concentrations of these metals were not statistically different between the sites. Barium, copper, and manganese were detected in broomsedge samples. Copper was significantly elevated in DA broomsedge compared to HE broomsedge. There was no difference in copper concentrations between HE and DA broomsedge samples. Manganese concentrations in broomsedge were significantly elevated on the DU area compared to DA broomsedge. Manganese was also significantly elevated in broomsedge on DA as compared to HE broomsedge samples.

10.11 HAZARD QUOTIENTS

The traditional HQ approach compares estimated exposures (mg contaminant/kg body weight-day) to screening toxicity values (e.g., chronic NOAELs) to estimate potential risk. If the HQ exceeds the conventional "threshold" value of 1.0, it is interpreted that there is potential risk to the receptors. Generally, the HQ calculation is a screening level tool.

10.11.1 Receptors

Receptors were selected based on their presence at the study sites, the availability of exposure and toxicological information, and their potential for exposure to contaminants. The meadow

vole (*Microtus pennsylvanicus*) was selected as the representative small mammal. The red-tailed hawk (*Buteo jamaicensis*) was selected as the avian species because red-tailed hawks were observed around the study sites. Reptiles and amphibians were not quantitatively evaluated due to the lack of toxicological data.

10.11.2 Exposure Assumptions

The ingestion pathway was the only pathway evaluated due to the lack of dermal and inhalation data in wildlife. The 95th UCL of the mean for each SOPC in soil and vegetation were used to estimate the exposure dose. If an SOPC was not detected in vegetation, the risk was calculated only using the soil concentration, and vice versa for vegetation. Potential exposure to water was not included in the ingestion pathway. It was assumed the small mammals were obtaining the majority of their water from the vegetation (Reich, 1981). Receptors are assumed to be exposed throughout their entire lifetime. For small mammals the non-soil portion of the diet (98%) was assumed to consist of 100% vegetation as represented by the two vegetation species collected (equal proportion of each). For the red-tailed hawk, the diet exposure dose was calculated based on the percentage of small mammals in their diet (12.6%, USEPA, 1993) assuming the bioavailability of contaminants from the small mammals to the hawk was equal to 1 for a worst-case scenario. Table 10-6 contains exposure parameters used in the risk estimation (USEPA, 1993).

TABLE 10-6 EXPOSURE ASSUMPTIONS

Parameter	Units	*M. pennsylvanicus*	*B. jamaicensis*
Normalized Ingestion Rate (total)	g wwt/g-day	0.33	.1
Calculated Diet Ingestion Rates			
Broomsedge	g bs wwt/g-day	0.1617	0
Woolgrass	g wg wwt/g-day	0.1617	0
Small mammals	g mam wwt/g-day	0	.013
Fraction of Soil in Diet	unitless	0.0066	0
Fraction of small mammal in diet	unitless	0	.126

10.11.3 Toxicological Benchmarks

The chronic lowest observed adverse effect level (LOAEL) for metal SOPCs (Table 10-7) were taken directly from Toxicological Benchmarks for Wildlife (Sample et al., 1996).

TABLE 10-7 CHRONIC LOWEST OBSERVED ADVERSE EFFECT LEVEL (LOAEL; MG/KG-DAY) FOR METALS AND EXPLOSIVES EVALUATED IN THIS STUDY

SOPC	Mammalian LOAEL	Avian LOAEL
METALS		
Antimony	1.25	data gap
Arsenic	1.26	7.38
Barium	19.8	41.7
Chromium	13.14	20
Copper	15.14	61.7
Lead	80	11.3
Manganese	284	977
Mercury	0.032	0.09
Molybdenum	0.26	data gap
Nickel	40	107
Uranium	11.2[a]	data gap
Vanadium	2.1	11.4
EXPLOSIVES		
Nitrobenzene	4.6	data gap
RDX	3.5[b]	data gap
Other		
Perchlorate	data gap	data gap

[a] Values obtained from ATSTR Uranium Toxicological Profile (ATSDR, 1999)
[b] Values obtained from USACHPPM Wildlife Toxicity Assessment (USACHPPM, 2001)

10.11.4 Risk Estimation

The following equations for risk estimation were adapted from the USEPAs Wildlife Exposure Factors Handbook (USEPA, 1993).

Equation 1-1

$$NIR_k = (P_k)(NIR_{total})$$

where:

NIR_k = Normalized ingestion rate of the k item in the diet (g/g-day)
P_k = percent of the k item in the diet (unitless)
NIR_{total} = Normalized ingestion rate of total diet (g/g-day)

Equation 1-2

$$E_{oral} = (C_{veg} \times NIR_{veg}) + (C_{soil} \times NIR_{soil})$$

where:

E_{oral} = average daily oral exposure (g/g-day)
C_{veg} = 95 UCL of the SOPC in vegetation (mg/kg)

NIR_{veg} = normalized ingestion rate of vegetation (g/g-day)
C_{soil} = 95 UCL of the SOPC in soil (mg/kg)
NIR_{soil} = normalized ingestion rate of soil (g/g-day)

Equation 1-3

$$HQ = \frac{E\ oral}{Tox\ Value}$$

where:
HQ = hazard quotient (unitless); above 1.0 indicated potential risk
E oral = average daily oral exposure (mg/kg-day)
Tox Value = lowest observed adverse effect level (LOAEL; mg/kg-day) or
USACHPPM derived Wildlife Toxicity Assessment (WTA)

10.11.5 Results and Uncertainty

Table 10-8 presents the hazard quotients (HQ) for each receptor on each site. There were only two HQs that exceeded the standard "threshold" value of 1.0. The exceptions were the HQs for the *M. pennsylvanicus* for manganese and nickel on the comparison area. All other HQs were below 1.

The analytical data for soil and vegetation are total concentrations of metals and are not necessarily representative of the percentage of SOPC that is bioavailable. The chronic LOAELs and exposure assumptions used produce conservative risk estimates. The HQ results support the conclusion that risk of adverse effects to small mammals and birds from SOPC exposure is low. These results are comparable to conclusions from studies at other artillery ranges that indicated the primary SOPCs were metals and the ecological risk was low (USACHPPM, 1998, USACHPPM, 2003).

10.12 DATA QUALITY INDICATORS

10.12.1 Precision

10.12.1.1 Analysis of Data

There are two approaches to the evaluation of field duplicate results. The first approach utilizes the relative percent difference (RPD) between the two results. The second approach utilizes the difference between the two results. The appropriateness of the two approaches is dependent upon the concentration of the analyte relative to the quantitation of detection limit for the analyte in the sample (Reference 6, Appendix A). The duplicate result for a single analyte will fall into one of three categories:

- both results were non-detected,
- one result was non-detected and the other result was a positive result, or
- both results were positive.

TABLE 10-8 HAZARD QUOTIENTS FOR THE REPRESENTATIVE SMALL MAMMAL AND BIRD

	Comparison (DA)		High Explosive (HE)		Depleted Uranium (DU)	
Analyte	*M. pennsylvanicus*	*B. jamaicensis*	*M. pennsylvanicus*	*B. jamaicensis*	*M. pennsylvanicus*	*B. jamaicensis*
Metals						
Antimony	4.5×10^{-3}	data gap	9.0×10^{-3}	data gap	nd	data gap
Arsenic	3.7×10^{-2}	2.5×10^{-4}	2.7×10^{-2}	1.8×10^{-4}	nd	nd
Barium	0.5	8.7×10^{-3}	0.5	8.8×10^{-3}	0.4	7.8×10^{-3}
Chromium	6.3×10^{-3}	1.6×10^{-4}	5.1×10^{-3}	1.3×10^{-4}	nd	nd
Copper	0.2	1.6×10^{-3}	0.2	1.5×10^{-3}	0.2	1.5×10^{-3}
Lead	2.4×10^{-3}	6.8×10^{-4}	1.5×10^{-3}	4.2×10^{-4}	nd	nd
Manganese	671	1.0×10^{-2}	0.7	7.6×10^{-3}	0.9	1.1×10^{-2}
Mercury	1.4×10^{-2}	2.0×10^{-4}	6.3×10^{-3}	8.8×10^{-5}	nd	nd
Molybdenum	1.9×10^{-2}	data gap	1.9×10^{-2}	data gap	nd	data gap
Nickel	15	2.4×10^{-4}	1.6×10^{-2}	2.4×10^{-4}	1.4×10^{-2}	2.1×10^{-4}
Uranium	1.73×10^{-4}	data gap	3.02×10^{-3}	data gap	2.94×10^{-4}	data gap
Vanadium	0.2	1.2×10^{-3}	7.5×10^{-2}	5.5×10^{-4}	nd	nd
Explosives						
RDX	2.4×10^{-5}	data gap	2.5×10^{-5}	data gap	nd	data gap
Nitrobenzene	nd[a]	data gap	8.0×10^{-3}	data gap	2.7×10^{-3}	data gap
Other						
Perchlorate	data gap	data gap	data gap	data gap	data gap	data gap

[a] nd = non detect, therefore HQ is not calculated

B DATA GAP = TOXICITY VALUE NOT AVAILABLE, THEREFORE HQ IS NOT CALCULATED

10.12.1.2 Evaluation Criteria

If both of the field duplicate results are greater than or equal to five times the method detection limit (MDL), the RPD must be less than or equal to 40% for solid samples (Reference 6, Appendix A). If the results exceed 40% the positive analytical results should be considered estimated.

If both of the field duplicates results are less than five times the MDL, the difference between the results must be less than or equal to twice the MDL.

When one of the duplicates samples was a not-detected result and the other was a positive result, the difference between the positive result and one-half of the MDL should be less than two times the MDL.

10.12.1.3 Discussion

A majority of the duplicate samples had results that were not-detected in both samples. These results did not need further analysis (see Tables 10-9 and 10-10). Two duplicate analyses had positive results that were greater than or equal to five times the MDL, and these results were within the specified acceptance limits. Three of the duplicate analyses had a not-detected result and the other result detected. Upon calculation this was shown to be less than two times the MDL and therefore is not considered to be estimated. Twenty-five of the duplicate analyses had

results less than or five times the MDL. Of these 25 analyses, only one of these samples (bolded in Table 10-9) resulted in a difference that was greater than two times the MDL, therefore being considered estimated.

TABLE 10-9 THE RELATIVE PERCENT DIFFERENCE OF DUPLICATES FOR BROOMSEDGE VEGETATION SAMPLES

Broomsedge												
	Impact				Comparison				Depleted Uranium			
	sample	duplicate	RPD	Difference	sample	duplicate	------ --- RPD	Difference	sample	duplicate	RPD	Difference
EXPLOSIVES												
HMX	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
RDX	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
1, 3, 5 – Trinitrobenzene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
1, 3 – Dinitrobenzene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Tetryl	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Nitrobenzene	nd, 0.05	0.2	---	0.15	nd	nd	0	0	nd	nd	0	0
2, 4, 6 – Trinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
4-Amino-2,6 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2-Amino-2,6 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2, 6 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2, 4 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2-Nitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
4-Nitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
3-Nitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
METALS												
Perchorate	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Antimony	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Arsenic	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Barium	10.2	8.34	---	1.86	8.18	6.62	---	1.56	5.7200	5.3600	---	0.36
Cadmium	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Chromium	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Copper	3.18	2.34	---	0.84	4.03	5.18	---	1.15	2.9300	3.2600	---	0.33
Lead	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Manganese	154	156	---	2.0	**234**	**375**	**---**	**141.0**	204	189	---	15.0
Mercury	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Molybdenum	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Nickel	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Silver	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Uranium	0.00181	0.0024	---	0.00059	0.00154	0.00524	---	0.0037	0.00378	0.00229	---	0.00149
Vanadium	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0

TABLE 10-10 THE RELATIVE PERCENT DIFFERENCE OF DUPLICATES FOR WOOLGRASS VEGETATION SAMPLES

Woolgrass												
	Impact				Comparison				Depleted Uranium			
	sample	duplicate	RPD	Difference	sample	duplicate	RPD	Difference	sample	duplicate	RPD	Difference
EXPLOSIVES												
HMX	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
RDX	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
1, 3, 5 – Trinitrobenzene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
1, 3 – Dinitrobenzene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Tetryl	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Nitrobenzene	0.2	0.2	---	0	nd	nd	0	0	nd, 0.05	0.2	---	0.15
2, 4, 6 – Trinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
4-Amino-2,6 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2-Amino-2,6 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2, 6 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2, 4 – Dinitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
2-Nitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
4-Nitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
3-Nitrotoluene	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
METALS												
Perchorate	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Antimony	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Arsenic	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Barium	24.8	21.3	---	3.5	28.1	32	---	3.9	21.5	10	---	11.5
Cadmium	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Chromium	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Copper	7.27	7.67	---	0.4	9.23	8.25	---	0.98	6.23	8.97	---	2.74
Lead	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Manganese	1340	1340	0	---	1060	1030	3.0	---	815	718	---	97.0
Mercury	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Molybdenum	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Nickel	nd, 1.0	2.06	---	1.06	2.21	2.37	---	0.16	nd	nd	0	0
Silver	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0
Uranium	0.00647	0.00646	---	0.00001	0.00523	0.00401	---	0.00122	0.00314	0.00351	---	0.00037
Vanadium	nd	nd	0	0	nd	nd	0	0	nd	nd	0	0

10.12.2 Accuracy

Accuracy/bias is a measure of the bias that exists in a measurement system and is also the degree of agreement between a samples theoretical and observed concentrations. When the measurement is applied to a particular set of observed values, it will be a combination of two components: a random component and common systematic error (or bias) component. Field sampling accuracy is usually assessed with equipment rinse blanks. As only dedicated sample equipment was used, no rinse blank samples were collected. All analytical data was validated by an independent review. The review included an evaluation of quality control sample data for all of the samples collected. Based on this review, all of the analytical results reported were considered valid and subsequently accurate.

10.12.3 Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The degree of representativeness is dependant on the thoroughness and proper design of the QAPP and Sampling and Analysis Plans (SAPs).

Vegetation species to be analyzed were selected after careful evaluation of four parameters: species dominance in study area, use as a food source by small mammals, ability to accumulate contaminants, and proximity of plants to craters.

10.12.4 Comparability

Comparability is an expression of the confidence with which one data set can be compared with another. Comparability of field data will be dependent upon the proper design of the sampling program and testing protocols. Study sites were matched for habitat, hydrogeology, and topography for data comparability.

10.12.5 Completeness

Based on the SAP, from each grid, two species of vegetation were collected, broomsedge and woolgrass. Two samples of each species were collected. Duplicates were to be collected from the fifth plant sampled, which would correspond to third grid on each study site. Due to an oversight, nitroglycerin was not an analyte. Eighteen samples were planned and collected (including duplicates) on each sampling site. With the exception of nitroglycerin, 100% of samples were collected as planned.

10.13 SUMMARY OF PROBLEMS

The initial comparison area was selected during a site scoping visit in April and was located near gate 15 on the western boundary of the installation. The site appeared to contain similar vegetation, hydrology, and habitat as the impact area sites during the May, 2002 scoping visit. However, upon returning to the installation in September to conduct trapping, it was apparent that the comparison site vegetation and hydrology were different from the impact area sites. Traps were set on this site for 2 nights with no success most likely due to habitat and heavy rains. It was decided to conclude trapping on this site, select a different comparison site, and to return in 2 weeks to trap the new comparison location. The new comparison site (DA) was located near gate 5 on the eastern boundary of the installation. The site was used as a UXO detection technology demonstration site by the AEC**.** In this demonstration, inert rounds were placed on the site and their locations were noted. Various UXO detection technologies were employed to determine the locations of the duds and remove them. After discussions with installation and AEC personnel, it was decided that the possibility that these inert rounds could have caused environmental contamination was low. This was due to their short duration in the field, 100% recovery of the rounds placed on the site, and the fact that they were inert (i.e., did not contain HE). No other sites on the installation were suitable for use as a comparison area. However, the analytical results for soil samples collected at this site showed that it is more contaminated with

explosive compounds than impact area soils. Metals concentrations were also generally greater in DA soils than in HE or DU soils.

The comparison site was trapped 2 weeks after the impact area trapping was completed due to the problems discussed above. This could have caused the differences observed in sperm parameters.

10.14 SUMMARY

The sperm count in *M. pennsylvanicus* was reduced on the impact area study sites. Since the comparison site was more contaminated than the impact area sites, the cause of these reductions are probably not chemically mediated. In addition, the observed reductions in count are below the assumed 80% reduction threshold required before reproductive effects are seen.

M. pennsylvanicus had a lesser incidence of abnormal sperm (morphology) on the DU area than the CA, and a greater incidence of abnormal sperm on the HE area than on the CA. The lack of consistency in results (increased abnormal sperm on comparison site as compared to HE site) and the fact that the comparison site is more contaminated than impact area sites indicate that the observed abnormalities are due to factors other than chemical stressors. In addition, the observed differences were well below the 4% difference needed to cause a reproductive effect.

The result trend for sperm motility was similar to sperm morphology (more motile sperm were observed from animals taken from the HE area than on the comparison site, and fewer motile sperm were observed in DU animals than on the comparison site). The lack of consistency in results and the fact that the comparison site is more contaminated than impact area sites indicate that the observed differences in motility are due to factors other than chemical stressors. In addition, the observed differences were well below the 40% difference needed to cause a reproductive effect.

The fact that the CA was more contaminated than the impact area, sperm counts were reduced on the less contaminated impact areas, the lack of consistency in morphology and motility results, and that any differences seen in sperm parameters did not exceed established thresholds, indicate that rodent populations at JPG are not being negatively impacted by SOPC contamination.

Organ to body weight ratios did not indicate that rodents are exposed to SOPCs.

Histpopathological evaluation did not indicate any chemically mediated changes in the histopathology of the organs collected from *M. pennsylvanicus*.
Hazard quotients for rodents and raptors did not exceed 1 on the impact area, indicating these receptors are not at risk due to SOPC exposure.

10.15 CONCLUSIONS

Based on the above weight of evidence, it appears that the small mammal population at JPG are not being affected by SOPCs attributable to test artillery range operations.

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